EXPLORING THE KEY FACTORS FOR BIM ACCEPTANCE IN CONSTRUCTION ORGANIZATIONS

Seul-Ki Lee[1] and Jung-Ho Yu[2]

[1] PhD. Student, Department of Architecture Engineering, Kwangwoon University, South Korea
[2] Associate Professor, Department of Architecture Engineering, Kwangwoon University, South Korea
Correspond to selkizz@kw.ac.kr

ABSTRACT: Substantial research has been performed on the data standards and exchanges in the AEC/FM industry over the past several years. The growing popularity of BIM technology is based heavily upon a perception that the technology can facilitate the sharing and reuse of information during a project life-cycle. Although many researchers and practitioners are in agreement about the potential applicability and benefit of BIM in construction, it is still unclear why BIM is adopted, and what factors enhance implementation of BIM. Thus, BIM acceptance and use remains a central concern of BIM research and practice. Therefore, we propose the key factors affecting the acceptance of BIM in construction organizations using factor analysis. The key factors for BIM acceptance are identified through a literature review in TAM (Davis 1989) and related theories, and consolidated by interviews and pilot studies with professionals in construction industry. Based on the factors, a questionnaire was designed and sent out to construction organizations such as contractors, architects, and engineers in Korea. Total 148 completed questionnaires were retrieved. Using factor analysis, key factors were grouped into six dimensions. These findings will clarify what the highly prioritized factors are, and can also be used in an assessment tool for the performance of BIM utilization.

Keywords: *Building Information Modeling (BIM); Technology Acceptance Model (TAM); Factor Analysis*

1. INTRODUCTION

In 2004, according to a NIST report, the capital facilities construction industry wastes $15.8 billion annually due to interoperability inefficiencies. These inefficiencies include the re-entry and re-creation of information and data, and a duplication of business functions [1]. Using Building Information Modelling (BIM), these inefficiencies can be solved [2]. BIM is "a new approach to design, construction, and facilities management, in which a digital representation of the building process [is used] to facilitate the exchange and interoperability of information in digital format [3]". In the construction industry, there is a growing interest in the use of BIM for coordinated, consistent, and computable building information/knowledge management from design to construction to maintenance and the operation stages of a building's lifecycle.

Although many researcher and practitioner are in agreement about BIM's potential applicability and benefits in construction, it is still unclear how BIM could be used, and what the benefits are to implementing BIM. Thus, BIM adoption and use remains a central concern of BIM research and practice. One of the key measures of implementation success is achieving the intended level of usage of the Information Technology (IT). The IT usage is a reflection of the acceptance of the technology by users [4]. There is a growing body of academic research examining the determinants of information technology acceptance and utilization among users [5 and 6]. In particular, the Technology Acceptance Model (TAM) [7] has served as a basis for previous research in dealing with behavioural intentions and usage of IT. The previous research argued in favour of investigating antecedent variables that can explain the core TAM variables and extend TAM in a way that enhances our ability to better understand the acceptance and usage of existing and new IT. Factors contributing to the acceptance of an IT are likely to vary with the technology, target users, and context [8]. Most of the prior studies have been carried out in traditional and relatively simple but important environments, such as personal computing, e-mail systems, word processing and spread sheet software [9]. The technology assessment theories provide a sound theoretical base for examining the factors influencing the use of BIM for construction organizations. Constructs for use in this study are based on those discussed in these theories. Theses constructs were selectively used based on their relevance in the BIM context as evidenced by previous surveys and case studies on the use of BIM.

Therefore, we propose the key factors affecting the acceptance of BIM in construction organizations using factor analysis. The key factors for BIM acceptance are identified through a literature review in acceptance related theories, and consolidated by interviews and pilot studies with professionals in BIM. Based on the factors, a questionnaire was designed and sent out to construction organizations such as contractors, architects, and engineers in Korea. Total 148 completed questionnaires were retrieved. Using factor analysis, key factors were grouped into six dimensions. These findings will clarify what the highly prioritized factors are, and can also be used in an assessment tool for the performance of BIM utilization.

2. THEORETICAL BACKGROUND

2.1 Acceptance behavior related theories

The goal of TAM [7] is to provide an explanation of the determinants of computer acceptance that is capable of explaining user behavior across a broad range of end-user computing technologies and user populations, while at the same time being both parsimonious and theoretically justified. In this model, perceived usefulness and perceived ease of use are of primary relevance for IS acceptance behavior. TAM proposes that external variables indirectly affect attitude toward use, which finally leads to actual system use by influencing perceived usefulness and perceived ease of use (Figure 1).

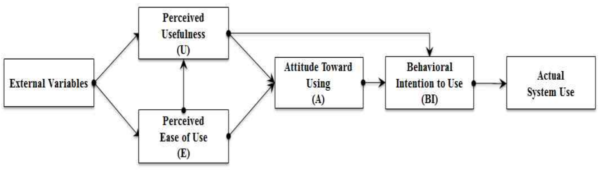

Figure 1 Technology Acceptance Model (TAM)

Hartwick and Barki [10] identified a mixed finding about a subjective norm. They found that a subjective norm had a significant impact on intention in a mandatory system use but not in voluntary settings. For this reason, the updated TAM, also called TAM2, extended the original TAM by including a subjective norm as an additional predictor of intention in the case of mandatory system use. The causal relationships and elements of TAM2 are described in Figure 2 [11].

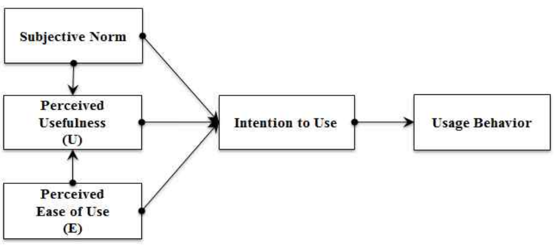

Figure 2 Technology Acceptance Model 2 (TAM2)

As another acceptance model, TTF matches the capabilities of a technology to the demands of the task. The availability of IT to support a task is expressed by the formal construct known as TTF, which implies matching of the capabilities of the technology to the demands of the task [12]. TTF posits that IT will be used if, and only if, the functions available to the user support (fit) the activities of the user. Rational, experienced users will choose those tools and methods that enable them to complete the task with the greatest net benefit. Information technology that does not offer sufficient advantage will not be used. TTF models have four key constructs: the first two are task characteristics, technology characteristics, which together affect the third construct task-technology fit, which in turn affects the final construct outcome variable, either performance or utilization.

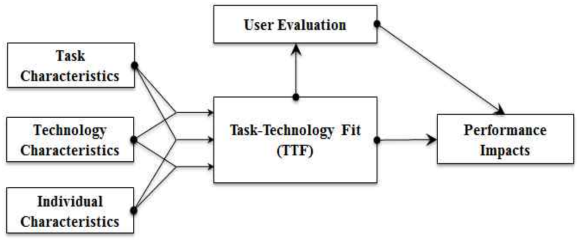

Figure 3 Task-Technology Fit Model (TTF)

2.2 External variable for technology acceptance

TAM (or TAM2) assumes that the effects of external variables (e.g., system characteristics, development process, training) on intention to use are mediated by perceived usefulness and perceived ease of use.

Table 1 presents the external variables considered from previous research. There is no clear pattern with respect to the choice of the external variables considered. The selection of external variables not only contributes to theory development, but also leads to improved technology acceptance. Actually, external variables provide a better understanding of what influences perceived usefulness and perceived ease of use, and the presence of external variables guides the actions required to influence a greater use.

Table 1 The type of external variables

Author	Technology	External variable
[6]	University computing	Compatibility, Peer Influence, Superior's Influence, Self-Efficacy, Resource Facilitating Conditions, Technology Facilitating Conditions
[13]	Spreadsheet, Database, Word processor, Graphics	Situational involvement, Intrinsic involvement, Prior use, Argument of change
[14]	Personal computing	Internal computing support, Internal computing training, management support, external computing support, external computing training
[15]	Multifunctional workstation	Perceived System Quality
[16]	MIS Application	Tool Experience, Tool Functionality, Task Technology Fit, Task Characteristics
[17]	Windows-based customer account management system	Voluntariness, Image, Job relevance, Output quality, Result demonstrability, Gender, Experience
[11]	Digital Libraries	Computer self-efficacy, Knowledge of search domain, Relevance, Terminology, Screen Design
[9]	E-services	Perceived Risk (Overall Risk, Performance Risk, Financial Risk, Privacy Risk, Time Risk, Psychological Risk, Social Risk)
[18]	Web-site	Anticipated Satisfaction, Social Approval, Expected Difficulty
[19]	E-shopping	Perceived Information Quality, Perceived System Quality, Perceived Service Quality, Web Security & Access Costs,

		User-Satisfaction
[20]	Web-based information	Relevance of information needs
[21]	ERP	ERP project communication, ERP training, Belief in the benefits of ERP project
[22]	Medical Record	Perceived Service Level
[23]	Internet Banking	Gender, Age, IT Competency
[24]	E-Learning	Cognitive Absorption (Temporal Dissociation, Focused Immersion, Heightened Enjoyment)
[25]	Electronic Tax Filing	Compatibility, Perceived Risk

The key factors were adopted from relevant prior research of technology behavior related theories and BIM for construction (Table2). The components for technology acceptance are broadly divisible into 1) Technology (BIM) related factor, 2) User (organizational, personal) related factor, and 3) Environment (pressure, support) related factor.

The definition of the adopted factors that comprise the BIM acceptance model in construction was made to tailor it in our context. In order to identify the key factors that may lead to a high acceptance of BIM, semi-structured interviews were conducted with ten BIM experts (BIM cooperators, designer, CMs, contractors, engineers, researchers). The interviews were selected based on their knowledge of and experience with the topic. Also, they have more than five years' experience and know that BIM can be used for their task. All of the key factors affecting the acceptance of BIM were measured on a seven-point likert scale from strongly disagree to strongly agree. From the result of measurement, all of the key factors become the further five points and are adopted.

Table 2 Items of BIM acceptance

No.	Items
T1	BIM tools that I use are connected to other IT tools (Smart phone, tablet PC).
T2	BIM tools that I use are easy for data input and output.
T3	Screen interface of BIM tools that I use are easily built so that everyone can use easily.
T4	BIM tools that I use are stable when using.
T5	BIM utilization improves information accessibility.
T6	Information acquired by using BIM is accurate and detailed.
T7	Enough information can be gathered using BIM.
T8	Information acquired by using BIM can be used throughout the course of the project.
T9	Benefit from using BIM is much higher than the setup cost (purchasing and upgrading software/hardware and user training).
T10	Benefit from using BIM is much higher than the cost for BIM utilization (modeling, data input and management).
U1	I don't have any resistance to using BIM.
U2	I am familiar with BIM tools.
U3	I understand the benefits of using BIM.
U4	I don't have psychological resistance to using a new information technology.
U5	I have technical capability of using a new information technology.
U6	I am aggressive about using a new information technology.
U7	My organization doesn't have any resistance to using BIM.
U8	My organization is familiar to BIM tools.
U9	My organization understands the benefits of using BIM.
U10	My organization doesn't have psychological resistance to using new information technology.
U11	My organization has technical capability of using new information technology.
U12	My organization is aggressive pushing to use new information technology.
E1	My organization supports enough resources (hardware and software) for BIM utilization.
E2	My organization provides proper education/training for BIM utilization.
E3	My organization provides incentives if we adopt or utilize BIM.
E4	My organization forces us to use BIM by setting up policies and regulations.
E5	I am required to use BIM by superiors and colleagues.
E6	Industry or government provides economic benefits if we adopt BIM.
E7	Industry or government provides proper education/training if we adopt BIM.
E8	Industry or government provides economic support for adopting, developing, and using BIM application technology.
E9	We are required to adopt BIM by project delivery or contract method
E10	We are required to adopt BIM by cooperative companies and cooperative relations.
E11	We are required to adopt BIM to satisfy owner's requirements.

Technology : T, User : U, Environment : E

3. RESEARCH METHODOLOGY

The data used to test the research model were obtained from a sample of experienced users (BIM cooperators, designer, CMs, contractors, engineers) of BIM. Each of items was measured on a seven-point scale varying.

Likert scales (1-7), with anchors ranging from "strongly disagree" to "strongly agree" were used for all questions. The questionnaire was sent by e-mail and mail, a total of 148 usable responses were obtained. Detailed descriptive statistics relating to the respondents' characteristics are shown in Table 3.

Table 3 Characteristics of the respondents (n=148)

Measure		Frequency	%
Sector of the respondent' Organization	BIM cooperator	34	22.97%
	Designer	36	24.32%
	CM	30	20.27%
	Contractor	33	22.30%
	Engineer	15	10.14%
Phase of BIM acceptance[1)]	Level 1	16	10.81%
	Level 2	12	8.11%
	Level 3	21	14.19%
	Level 4	45	30.41%
	Level 5	54	36.49%
Respondent's average experience	Construction Industry	Approx. 6 years	
	BIM	Approx. 1 years	
BIM related education or training		Approx. 20.41 hours	
Total		148	100%

1) **Level1** We are aware of the BIM technology but we don't know how to use BIM and the benefit of it
Level2 We are interested learning more about the positive aspect of using BIM
Level3 We will consider if its usage is meaningful
Level4 We have accepted BIM in a small scale
Level5 We continue to use BIM for all projects

4. THE KEY FACTORS FOR BIM ACCEPTANCE

4.1 Factor analysis of the key factors

Analysis is used to identify a relatively small number of factor groups that can be used to represent relationships among sets of many inter-related variables". In this survey, this method was used to determine the groupings of the 33 key factors.

According to Pallant[26], 2 main issues have to be considered in determining whether a data set is suitable for factor analysis: sample size and the strength of the relationship among the factors. In terms of sample size, According to Hair et al.[27] at least 4-5 times the number of variables is appropriate. There were 33 factors in this survey, so according to Hair et al.[27] recommendation, from 132 to154 respondents should be obtained in this study. Therefore the sample size was enough for factor analysis. In terms of the strength of relationship among the factors, the correlation matrix[28], the Bartlett's test of sphericity [29] and the Kaiser-Myer-Olkin(KMO)[30] were recommended.

Most values in the correlation matrix are larger than 0.3, the Bartlett's test of sphericity is significant($p<0.05$), and the value of the KMO index is above 0.6, suggesting the data set is suitable for factor analysis. In this survey, all of the correlation coefficients were above 0.3, the Bartlett's test of sphericity was significant ($p<0.05$) (Table 4), and the value of the KMO index was 0.859 (above 0.6). The results of these tests confirmed that the data were appropriate for factor analysis.

A 6-component was produced based on varimax rotation of principal component analysis (Table 4). There six factor groupings with Eigen value greater than 1.0 explain 72.337% of the variance. Each of the key factors belonged to only one of the groupings, with the value of factor loading exceeding 0.5 [31].

However, 'E3: my organization provides incentives if we adopt or utilize BIM.' is loaded in the component 1 (0.4060), but did not delete. Because this item verified content validity by conducting interview with BIM experts and not interfere with the unidimensionality (Table 5).

The following Table 4 shows the results of factor analysis.

Table 4 Result of reliability and validity test

Component	Items	Factor Loading	Eigen value	Cumulative %	Cronbach'α
1	U10	0.8705	5.760	17.454	0.932
	U11	0.8374			
	U12	0.8328			
	U9	0.7893			
	U7	0.7423			
	U8	0.7198			
	E1	0.6890			
	E2	0.6042			
	E3	0.4060			
2	T4	0.8133	5.177	33.143	0.914
	T6	0.7957			
	T7	0.7739			
	T2	0.7733			
	T5	0.7695			
	T3	0.7591			
	T1	0.7191			
	T8	0.5649			
3	U6	0.8374	4.627	47.164	0.927
	U5	0.8004			
	U2	0.7914			
	U4	0.7854			
	U3	0.7654			
	U1	0.7478			
4	E11	0.8174	3.197	56.852	0.865
	E10	0.8046			
	E9	0.8015			
	E4	0.6563			
	E5	0.5527			
5	E6	0.8505	3.142	66.373	0.914
	E7	0.8220			
	E8	0.8125			
6	T9	0.8019	1.968	72.337	0.814
	T10	0.7808			

Kaiser-Meyer-Olkin measure of sampling adequacy		0.859
Bartlett's test of Sphericity	Approx. Chi-Square	4133.085
	df.	528
	Sig.	0.000

1) Component 1: Organizational Competency

This component, which accounted for 17.454% (Table 4) of the total variances between key factors, was relatively more important than the other five components. Items included this component is defined as 'Organizational competency'. It indicated that organizational competency is important issue of BIM acceptance.

'Organizational competency' can be largely divided into three groups: collective efficacy (U7, U8, and U9), organizational innovativeness (U10, U11, and U12) and top management support (E1, E2, and E3).

Collective Efficacy: This concept refers to the organizational dimension to inquire about efficacy beliefs in organizations. Inquiry into collective efficacy beliefs emphasizes that teachers have not only self-referent efficacy perceptions but also beliefs about the conjoint capability of users. Such group referent perceptions reflect an emergent organizational property known as perceived collective efficacy [32, and 33].

Organizational Innovativeness: We defined that organizational innovativeness as "the willingness of an organization to try out any new information technology". To successfully accept BIM, effective collaboration and clear role sharing for modeling among construction organizations are necessary. Then, all construction organizations should comply with the standardized policies and procedures for modeling. Therefore, personal innovativeness as well as organizational innovativeness should be considered.

Top management support: Top management support has extensively been recognized as an important variable in technology implementation studies [34]. The decision by an organization to adopt BIM may by a risky decision for the organization unless there is a firm commitment from top management. Gillgan and Kunz [34] found that top management commitment was one of the major success factors for adopting BIM technologies. It is anticipated that firms that have significant top management support for adoption for BIM are more likely to it.

2) Component 2: Technology Quality

This component ranked second among the five components. 'Technology quality' factors can be largely divided into two groups; Compatibility (T1, T2, T3, and T4), and output quality (T5, T6, T7, and T8).

Compatibility: Compatibility, defined as the degree to which the technology fits the potential adopter's previous experience, work practice, used system and needs, has been identified as an essential factor for innovation adoption [35]. Considerable prior research has reported a significant effect of compatibility on the user technology acceptance decision.

Output Quality: In the construction industry there is a growing interest in the use of BIM in construction for coordinated, consistent, and computable building information/knowledge management. The information collected through a BIM process and stored in a BIM compliant database could be beneficial for a variety of construction practices. Therefore, output quality of BIM is measured by capability of search, accessibility and trust of information.

3) Component 3: Personal Competency

This component ranked third among the five components. We defined this component as 'personal competency'. 'Personal competency' factors can be largely divided into two groups; self-efficacy (U1, U2, and U3), and personal innovativeness (U4, U5, and U6).

Self-Efficacy: The concept of self-efficacy originates from social cognitive theory [36]. It refers to the conviction that one can successfully execute the behavior required to produce the outcome. Self-efficacy is used as perceived behavioral control, which means the perception of the ease or difficulty of the particular behavior. It is linked to control beliefs, which refer to beliefs about the presence of factors that may facilitate or impede performance of the behavior.

Personal Innovativeness: Personal innovativeness is defined as "the willingness of an individual to try out any new information technology". According to Agarwal and Prasad [37], personal innovativeness helps identify individuals who are likely to adopt information technology innovations earlier than others. Learning a person's individual innovativeness would help us to further understand both how perceptions are formed and the subsequent role they play in the formation of individual behavior.

4) Component 4: Behavior Control

This component ranked fourth among the five components. We defined this component as 'Behavior control'. 'Behavior control' factors can be largely divided into two groups; external pressure (E9, E10, and E11), and internal pressure (E4, and E5).

Internal Pressure: internal pressure means the impacts by superior and colleague within the organization. Venkatesh and Davis [11] found that internal pressure had a significant impact on intention in mandatory system. In mandatory settings, social influence appears to be important only in the early stages of individual experience with the technology, with its role eroding over time and eventually becoming non-significant with sustained usage.

External Pressure: External pressure involves the influences arising from several sources within the competitive environment surrounding the organization. Enacted user power measures the strength of the influence strategy used to exercise that potential power.

5) Component 5: Expected External Reward

This component ranked fifth among the five components. We defined this component as 'Expected External Reward' (E6, E7, and E8).

Expected External Reward: External (e.g. industry and government) rewards can range from monetary incentives such as increased benefit and market share. Thus, this study expects that if organizations believe they can receive external rewards by using BIM, they will develop more positive attitudes toward and intentions regarding the use of BIM.

6) Component 6: Cost

Though this component is the lowest ranked among the three components (Table 4), it is indispensable for BIM acceptance (T9, T10).

Cost: Rogers [38] noted that the less expensive an innovation is, the more likely it is to be adopted. The cost of an innovation includes the initial investment cost as well as the operations and training costs that facilitate effective use of the technology [39]. In previous technology assessment research, cost has been suggested as a major barrier to widespread adoption of innovative technologies [40]. Related research on BIM adoption has also shown that cost of BIM technology is a major factor [34, 40, and 41]. It is anticipated that firms that perceive BIM technology to be relatively less costly are more likely to adopt it.

4.2 Validation of the key factors

1) Testing for reliability

A α value higher than 0.7 is considered to be relatively more reliable. As shown table 4, the result of the reliability test is 0.814 to 0.938. Therefore, this provides evidence that all the factors have a high internal consistency and reliability.

2) Testing for content validity

To ensure the content validity, our survey was established from the existing literature. In addition, our measures were constructed by adopting constructs validated by other researchers. Also, we conducted pretesting with experts in the field of BIM in construction. After the pretesting, these items were modified to fit the construction context studied.

3) Testing for construct validity

Construct validity was used to check for unidimensionality. Unidimensionality means that a single factor is extracted for each test. Each factor grouping was evaluated by factor analysis for construct validity. The table 5 presents results of the unidimensional test. Since all of the KMO values were greater than 0.5, and the percentage of variance explained by each component was more than 50%, all 6 components were demonstrated to be unidimentional.

Table 5 Result of unidimensionality test

Component	KMO value	Factor Loading	Eigen value	Percentage variance explained
1	0.894	0.889-0.561	5.884	65.509
2	0.868	0.643-0.874	5.035	62.932
3	0.886	0.875-0.816	4.401	73.346
4	0.751	0.750-0.838	3.247	64.931
5	0.752	0.938-0.913	2.561	85.350
6	0.5	0.929, 0.929	1.726	86.305

5. DISCUSSION AND FUTURE WORKS

Substantial research over the past several years has been performed on the data standards and exchange in the AEC/FM industry. The growing popularity of BIM is based heavily upon a perception that the technology can facilitate the sharing and reuse of information during a life-cycle.

The main contribution of this study is identifying an ordered and grouped set of key factors for BIM acceptance in the Korean construction industry. To achieve object of our research, 33 key factors were identified through a literature review of acceptance behavior related theories such as TAM [7], and TTF [12], and semi-structured interviews which were conducted with BIM experts. Using factor analysis, the 33 key factors were grouped into six dimensions: Organizational Competency, Technology Quality, Personal Competency, Behavior Control, Expected External Reward, and Cost.

Factor analysis results are as follows.

▪‘Organizational Competency’ included 9 items. Also, this factor consists of three groups (collective efficacy (U7, U8, and U9), organizational innovativeness (U10, U11, and U12) and top management support (E1, E2, and E3))

▪‘Technology Quality’ included 8 items. Also, this factor consists of two groups (Compatibility (T1, T2, T3, and T4), and output quality (T5, T6, T7, and T8)).

▪‘Personal Competency’ included 6 items. Also, this factor consists of two groups (self-efficacy (U1, U2, and U3), and personal innovativeness (U4, U5, and U6)).

▪‘Behavior Control’ included 5 items. Also, this factor consists of two groups (external pressure (E9, E10, and E11), and internal pressure (E4, and E5)).

▪‘Expected External Reward’ included 3 items.

▪‘Cost’ included 3 items.

In order to improve the ability to describe the relationships between the key factors (which were derived in this research) that may lead to the high acceptance of BIM in construction organization, the BIM acceptance model needs to be verified by applying additional parameters such as perceived usefulness, perceived ease of use, and intention of acceptance that have been presented in existing technology acceptance models.

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